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Counterweights Used with ANVIS

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A survey was conducted at Fort Rucker, Alabama, on the use of counterweights with the aviator night vision imaging system (ANVIS). The purposes of the survey were to determine frequency and purpose of counterweight use, materials used, and actual weight of the counterweights. Thirty-seven night vision goggle (NVG) instructor pilots (IPs) and nineteen NVG student pilots contributed to this survey. NVG participants flew four different aircraft types located at three different airfields.

The results showed that 76 percent of the NVG IPs used counterweights. Average weight for the counterweights was 13 oz with a minimum of 8.9 and a maximum of 22 oz. For the graduating NVG student pilots, 100 percent used counterweights. The average counterweight used by the students was 11.7 oz with a minimum of 3.4 and a maximum of 20.1 oz. The two primary reasons listed for using counterweights were to reduce the helmet from rotating forward and to relieve neck strain. The most common type of counterweight consisted of a standard issued cloth bag with two to three rolls of pennies. In the heaviest possible configuration, the head supported weight with ANVIS could be (continued)

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as much as 7.3 pounds lbs, which includes an X-Large SPH-4 helmet, 25-mm eyepiece ANVIS with dual battery pack and AA batteries, 20 oz of counterweight, a lip light, and an ANVIS head-up display (HUD). Of the 37 NVG IPs surveyed, the average estimated head supported weight with ANVIS was 5.7 lbs, with a minimum of 4.7 and a maximum of 6.8 lbs. With the addition of a protective mask the total weight would increase by approximately 2 pounds.

An epidemiological analysis of 357 helicopter accidents involving 704 pilots and copilots from 1985 to 1994 showed 10 percent of the NVG (ANVIS and AN/PVS-5) pilots had some type of neck injury versus 9.2 percent of the pilots without NVGs in the combined survivable and partially-survivable accident categories. With this same survivable and partially-survivable data base, 28.6 percent of the NVG pilots had head injuries versus 16.5 percent of the pilots without NVGs.

ABSTRACT

A survey was conducted at Fort Rucker, Alabama on the use of counterweights with the aviator night vision imaging system (ANVIS). The purposes of the survey were to determine frequency and purpose of counterweight use, materials used, and actual weight of the counterweights. Thirty-seven night vision goggle (NVG) instructor pilots (IPs) and nineteen NVG student pilots contributed to this survey. NVG participants flew four different aircraft types located at three different airfields.

The results showed that 76 percent of the NVG IPs used counterweights. Average weight for the counterweights was 13 ounces (oz) with a minimum of 8.9 and a maximum of 22 oz. For the graduating NVG student pilots, 100 percent used counterweights. The average counterweight used by the students was 11.7 oz with a minimum of 3.4 and a maximum of 20.1 oz. The two primary reasons listed for using counterweights were to reduce the helmet from rotating forward and to relieve neck strain. The most common type of counterweight consisted of a standard issued cloth bag with two to three rolls of pennies. In the heaviest possible configuration, the head supported weight with ANVIS could be as much as 7.3 pounds (lbs), which includes an X-Large SPH-4 helmet, 25-mm eyepiece ANVIS with dual battery pack and AA batteries, 20 oz of counterweight, a lip light, and an ANVIS head-up display (HUD). Of the 37 NVG IPs surveyed, the average estimated head supported weight with ANVIS was 5.7 lbs, with a minimum of 4.7 and a maximum of 6.8 lbs. With the addition of a protective mask the total weight would increase by approximately 2 pounds.

An epidemiological analysis of 357 helicopter accidents involving 704 pilots and copilots from 1985 to 1994 showed 10 percent of the NVG (ANVIS and AN/PVS-5) pilots had some type of neck injury versus 9.2% of the pilots without NVGs in the combined survivable and partially-survivable accident categories. With this same survivable and partially-survivable data base, 28.6 percent of the NVG pilots had head injuries versus 16.5 percent of the pilots without NVGs.

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Background

Night vision goggle (NVG) training at Fort Rucker, Alabama began around 1978 with the AN/PVS-5 NVG. These NVGs were designed for the infantry and were attached to the head with an adjustable head harness. For aviation use, the NVGs were initially attached to the helmet with straps and snaps, and later with surgical tubing. The AN/PVS-5 NVGs weighed approximately 2 lbs (.91 kilograms) with the center of gravity (C.G.) located approximately 6 inches forward of the tragion, or head's center of mass. With the SPH-4 helmet and the AN/PVS-5 NVG, the aviator had approximately 5.5 lbs (2.5 kg) of head supported weight with the C.G. forward of the acceptable limits.

Counterweights with NVGs were forbidden until 1983 (Jones, 1983). It was well known by the aviator NVG user community that although the counterweights increased the head supported weight, they also helped stabilize the NVGs and reduced neck fatigue. A previously unpublished 1981 U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, survey of NVG instructor pilots (IPs) found that approximately 70 percent of the participating IPs were using some form of counterweight even before counterweights were authorized. The mean and median weight values were almost exactly those calculated by USAARL to place the head supported weight and C.G. at the head's center of mass. USAARL recommended, and U.S. Army Aviation Center approved and authorized a maximum of 22 oz. of counterweight with the NVGs.

From informal surveys, it is known that not all of the NVG IPs used counterweights with ANVIS; whereas their use is absolutely essential with the AN/PVS-5 NVG modified faceplate in order to obtain eyepiece alignment and stability (McLean, 1983). The dual battery pack and the heavier AA batteries, instead of the original lithium batteries, mounted on the back of the helmet for the ANVIS provide approximately 10 oz of counterweight. Additionally, some aviation units are using the 25-mm eyepiece ANVIS, which results in a small increase in weight compared to the standard 18-mm eyepiece. However, to optimize the unaided look around field of view and to retain the full image intensified field of view, the ANVIS should be moved approximately 10 mm further from the eyes with the 25-mm eyepiece, thus increasing the forward C.G.

Several helmet mounted displays proposed for the Comanche helicopter and the Advanced Visionics System will have a forward C.G. The head supported weight given by the helmet mounted display (HMD) developers do not include counterweights. There is a strong probability that if the HMD C.G. is similar to ANVIS or more forward, the users will use counterweights for both stability and neck comfort, thus increasing the head supported weight. Unlike the ANVIS, which has a forward break-away feature when subjected to impact forces between 10 to 15 Gs, some of the proposed advanced HMDs have not included this break-away feature. Thus, the forces on the neck during a mishap could increase the risk of a severe neck injury. The present survey was initiated to determine the percent of IPs using counterweights, the reasons for using a counterweight, the types of counterweights used, and the amount of counterweight used by the most experienced NVG pilots for the standard ANVIS.

Method

A total of 37 NVG IPs at Lowe, Cairns, and Hanchey Army Airfields, Fort Rucker, Alabama, participated in this survey. The types of aircraft used by the participants were UH-1, OH-58A/C, OH-58D, and UH-60A. Nineteen students from Lowe Army Airfield, who were at the end of their NVG qualification course, also participated.

At the airfields, a questionnaire was used to collect information such as the number of NVG hours, helmet type and size, and reasons for using a counterweight. Appendix A contains the questionnaire and briefing given to the NVG pilots who volunteered for this survey. The counterweights were weighed with a portable electronic scale, and the materials used for the counterweights were recorded by the investigators.

An electronic scale was used in the Laboratory to determine the weights of a dual battery pack, ANVIS, a single sample of the helmet types, and auxiliary equipment such as a lip light, head-up display (HUD), and the optical display assembly (ODA). Using extra-large SPH-4 and SPH-4B helmets with ANVIS mounts, the weight and center of gravity (C.G.) were measured with the combinations of the ANVIS, dual battery pack, and 12 oz of counterweight. A description of the equipment and method of measuring the mass and C.G. can be found in a report by Deavers and McEntire (1992). The single sample head supported weights list, graph of the weight, and C.G. for the SPH-4 and SPH-4B helmets with and without ANVIS and counterweights are located in Appendix B.

An epidemiological survey was conducted to determine the frequency of incidents of neck and head injuries among Army pilots in rotary-wing accidents between 1985 to 1994 using the U.S. Army Safety Center's Automated Safety Management System (ASMIS). Accident types were limited to Class A-C categories involving "impact with the ground" for aircraft routinely using NVGs. A description of accident categories can be found in DA-PAM 385-95 (1983). The accidents were classified into NVG and non-NVG flights, and again subclassified into the ASMIS survivable, partially survivable, and nonsurvivable.* Significant differences between the relative risks of head and neck injuries with and without NVGs were determined using the 95 percent confidence interval.

* A more in-depth description of methology, findings, and statistical analysis are being published in a USAARL technical report titled, "U.S. Army Aviation Life Support Equipment Retrieval Program: Head and Neck Injury among Night Vision Goggle Users in Rotary-wing Mishaps" by Samuel G. Shannon and Kevin T. Mason.

Results

NVG instructor pilots

For the NVG IPs, table 1 lists the aircraft type, number of participants, percent of the participants using counterweights (CTWT), and the airfields at Fort Rucker where the pilots were assigned.

Table 1.
Summary of counterweight use (IP)

Aircraft	Number	CTWT use	Location
UH-1H	5	100%	Lowe AAF
OH-58A&C	11	100%	Lowe AAF
OH-58D	5	60%	Hanchey AAF
UH-60A	16	56%	Cairns AAF
- Totals	37	76%	----------

Note: For the counterweights included in the data, median = 11.6 oz; mean = 13.0 oz; SD = 3.7 oz; and range, 8.9 - 22 oz.

Figure 1 shows a plot of the frequency distribution of the amount of counterweights used by the instructor pilots in 2 oz increments. The labelled counterweight mid points include -1.00 to +0.99 oz of the value for each bar in the graph. Figure 2 shows the data plotted as a cumulative distribution, listing the 10th, 50th, and 90th percentile values.

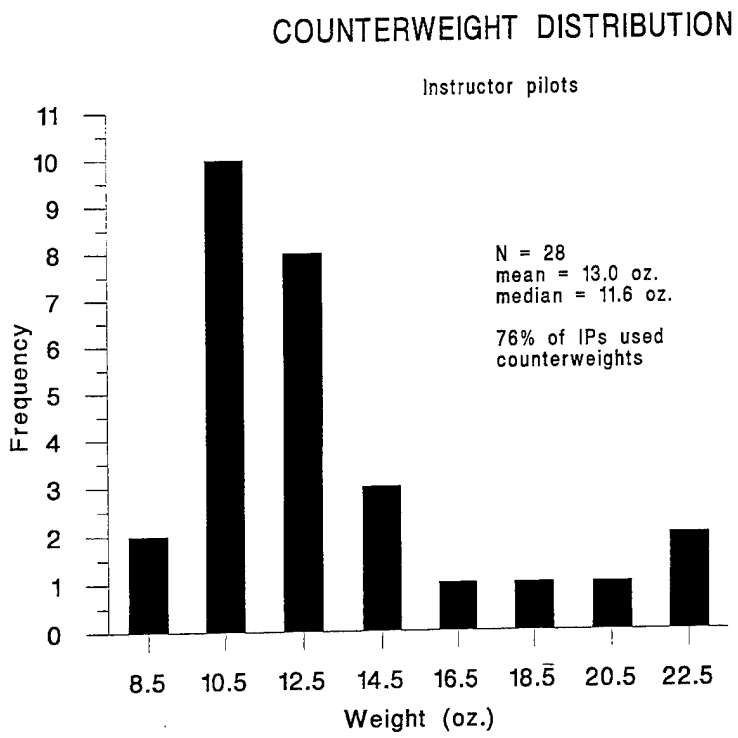

Figure 1. Frequency distribution of counterweights used by IPs.

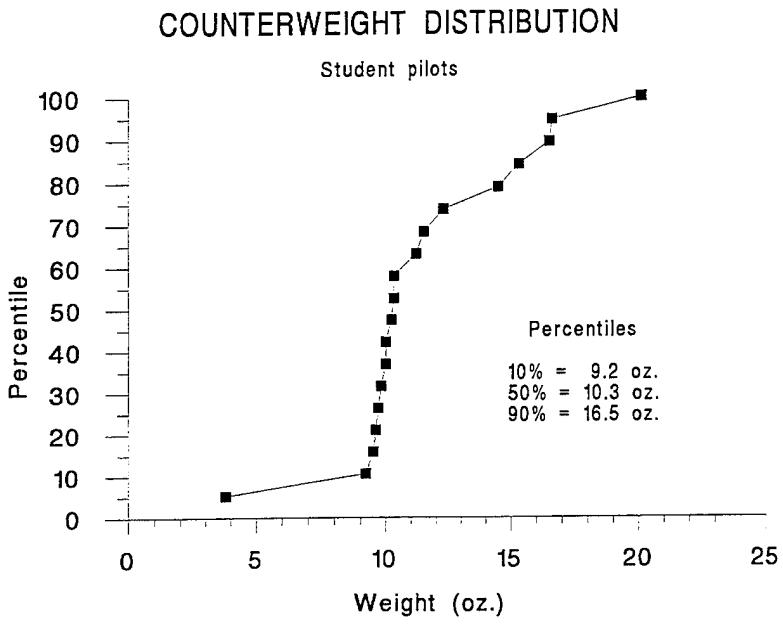

Figure 2. Cumulative distribution of counterweights used by IPs.

Ninety-three percent of the IPs used the standard cloth bag to contain their counterweights, and seven percent used solid weights that were attached to the helmet with Velcro™. Table 2 lists the materials and percentage of each type used by the pilots.

Table 2.
Counterweight types*
and percent using this type (IP)
N=28

pennies	50%
fishing or tire weights	21%
buckshot	14%
solid weight	7%
batteries	4%
nuts and bolts	4%

* The NVG counterweights are not government supplied.

Table 3 is a statistical description of the NVG flight time of the IPs broken down by ANVIS and total NVG flight hours.

Table 3.
Night vision goggle experience (IP)
N=37

	mean	SD	min	max
ANVIS hours	381	298	50	1500
All NVG hours	543	498	110	2500

Table 4 lists the characteristics of the helmets used by the IPs such as type, suspension, size, and thermal plastic liner (TPL) modifications.

Table 4.
Helmet characteristics (IP)
N=37

type	72% SPH-4B	28% SPH-4
suspension	97% TPL	3% custom
size	49% Regular	51% X-Large
TPL heat treated?	14% Yes	86% No
no. dimple liners removed	mean 1.1	max 3

When the 37 IP subjects were asked if they obtained a full field of view with the ANVIS, 78 percent responded "Yes," and 22 percent responded "No."

Of the 37 subjects who were asked how they adjusted the ANVIS fore-aft position, the following results were listed:

41 percent responded "as close to the eyes as possible"
59 percent responded "close enough to obtain a full FOV with sufficient look around to read my instruments"
0 percent responded "as far from eyes as possible"

Reasons given for using a counterweight were ranked by the participants, where 1 was the most important, 2 was the next, and so on. The participants ranked three of the four reasons listed on the questionnaire as the most important. For analysis, the ranking numbers were reversed so that a 1 was scored a value of 3, a ranking of 2 was scored a 2, and a ranking of 3 was scored a value of 1. A value of 0 was given to options not ranked. Table 5 lists the order of ranking, the reasons given for counterweight use, the mean of the ranking (reversed), and the percent that a specific response was ranked number one.

Table 5.
Reasons for using a counterweight (IP)
N=28

Ranking order	**Reasons listed**	**Mean score**	**Percent no. 1**
1	to relieve neck strain	2.3	46%
2	to reduce helmet from rotating forward	2.1	42%
3	to keep eyes aligned with NVG	1.4	12%
4	NVG instructor recommended it	0.04	00%

NVG student pilots

All 19 of the students surveyed were using counterweights and were flying the UH-1H aircraft at Lowe AAF. All students had approximately the same number of NVG flight hours. The mean of ANVIS flight hours was 17.2 with a minimum of 14 and a maximum of 18 hours.

Figure 3 shows the frequency distribution of counterweights (median 10.3 oz, mean 11.6 oz, SD 3.5 oz, range 3.8 - 20.1 oz) used by student pilots near the completion of the NVG qualification course. Figure 4 shows a percentile cumulative distribution of counterweights used by the student pilots, listing the 10th, 50th, and 90th percentile values.

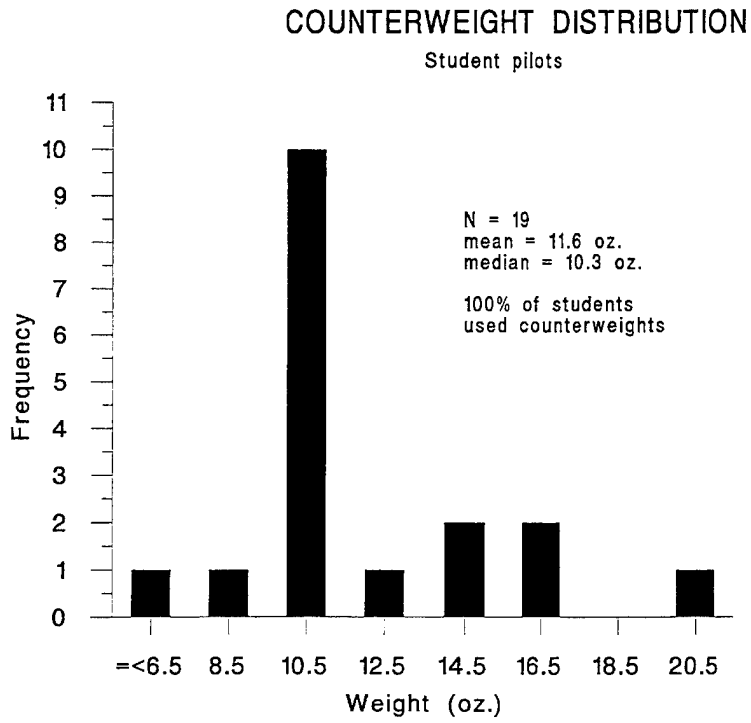

Figure 3. Frequency distribution of counterweights used by students.

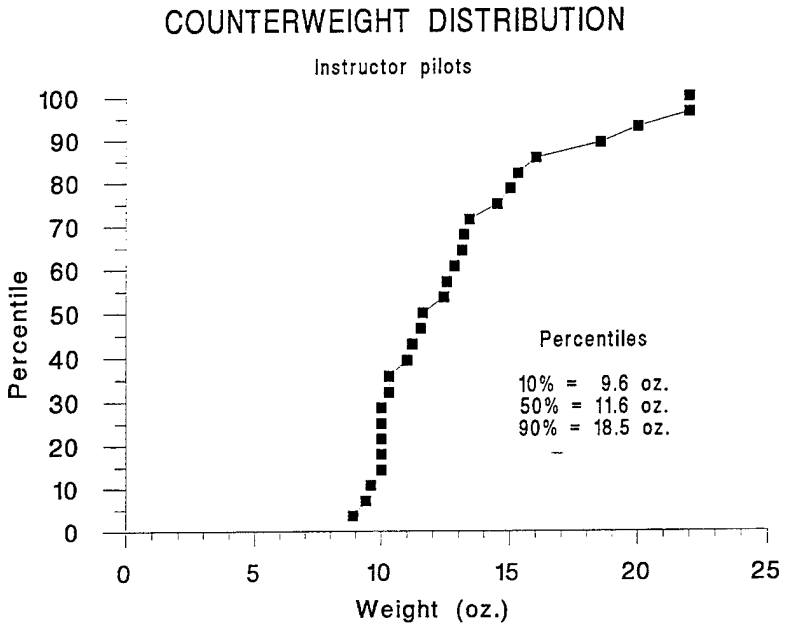

Figure 4. Cumulative distribution of counterweights used by students.

All of the 19 students surveyed were using the standard cloth bag to hold their counterweights. No solid weights were found. Table 6 lists the type of counterweights and percent of the total. The values sum to 99 percent due to rounding-off error.

Table 6.
Counterweight types and percent using this type (students)
N=19

pennies	79%
batteries	15%
fishing or tire weights	5%

Table 7 lists the characteristics of the helmets used by the students such as type, suspension, size, and TPL modifications.

Table 7.
Helmet characteristics (students)
N=19

type	84% SPH-4B	16% SPH-4
suspension	100% TPL	00% Sling
size	37% Regular	63% X-Large
TPL heat treated?	11% Yes	89% No
no. dimple liners removed	mean 0.37	max 2

Of the 19 student subjects who responded to the question as to whether they obtained a full field of view with the ANVIS, 100 percent responded "Yes." When asked how they adjusted the ANVIS fore-aft position, the 19 subjects provided the following results:

58 percent responded "as close to the eyes as possible"
32 percent responded "close enough to obtain a full FOV with sufficient look around to read my instruments"
11 percent responded "as far away from eyes as possible"

Reasons given for using a counterweight were ranked by the students. As previously explained in the IP results, the mean ranking scores were determined by reversing the ranking numbers and averaging. Table 8 lists the order of ranking, the reasons given for counterweight use, the mean score of the ranking (reversed), and the percent that a specific response was ranked number one.

Table 8.
Reasons for using a counterweight (students)
N=19

Ranking order	**Reasons listed**	**Mean score**	**Percent no. 1**
1	to relieve neck strain	2.1	53%
2	to reduce helmet from rotating forward	2.0	32%
3	to keep eyes aligned with NVG	1.0	11%
4	NVG instructor recommended it	0.8	5%

Epidemiological helicopter accident data

With the additional head supported weight associated with NVGs, we hypothesized that an epidemiological study of helicopter accidents would show an increased risk of head and neck injuries among NVG users in ground impact accidents. To test this hypothesis, we abstracted data from the U.S. Army Safety Center's ASMIS database on all helicopter mishaps which occurred during the ten-year period between January 1, 1985 to December 31, 1994. From these mishaps, we selected cases which involved aircraft series in which NVGs were likely to be worn. Mishaps which did not list the specific type of NVG worn by the crewmember and mishaps which involved NVG types which were not of standard issue (N = 7) were excluded from the analysis.

There were 704 pilots and copilots involved in the 357 rotary-wing accidents that involved ground impact during the ten-year period evaluated. Of these, 168 were wearing night vision goggles (48 AN/PVS-5 and 120 ANVIS), with 128 in survivable and partially survivable mishaps. Of the 536 pilots and copilots involved in accidents not involving NVGs, 454 of these were in the survivable and partially survivable categories. Table 9 lists the percent of neck and head injuries with and without AN/PVS-5 and ANVIS NVGs for the combined categories of survivable and partially survivable, and nonsurvivable accidents.

Table 9.
Percent injuries per accident
N=704

	Survivable & Partially Survivable		Nonsurvivable	
NVG type	**Neck**	**Head**	**Neck**	**Head**
AN/PVS-5 N=48	18% (6/34)	38%* (13/34)	36% (5/14)	93% (13/14)
ANVIS N=120	8% (7/92)	25% (23/92)	11% (3/28)	71% (20/28)
No NVG N=536	9% (41/455)	17% (77/455)	31% (25/81)	79% (64/81)

*$p < 0.05$

Unexpectedly, there was no significant difference in the relative risk of neck injuries with and without either type NVG for the combined categories of survivable and partially survivable or the nonsurvivable accidents, although there appears to be a higher percentage of neck injuries with survivable and partially survivable mishaps when using the AN/PVS-5 NVGs. However, the

difference in the percent head injuries with AN/PVS-5 NVGs for survivable accidents is significant at the .05 level of confidence.

Discussion

In this study, the primary factor that seems to determine whether or not a pilot uses a counterweight with ANVIS appears to be related to the aircraft type or airfield location. It was noted that all of the NVG IPs and students flying UH-1 helicopters surveyed at Lowe AAF used counterweights. We suspect that flight commanders or senior NVG instructor pilot opinions may have a strong influence on the use of counterweights with ANVIS for a given unit. Several of the IPs stated that they had previously used counterweights with ANVIS but had lost the weight bag. The counterweights were not replaced, and they found they could use the ANVIS without a counterweight.

Because of the increase in forward C.G., it was speculated that a higher percentage of the ANVIS pilots would need more counterweight when using the ANVIS HUD or ODA. However, this was not found with our small sample of pilots using the HUD with ANVIS.

The total head supported weight with ANVIS varies with helmet size, helmet type, battery pack, auxiliary equipment, and the amount of counterweight. In the lightest configuration, a pilot using a regular size SPH-4B helmet, 18-mm eyepiece ANVIS with a standard battery pack, and no counterweight would have a head supported weight of approximately 4.7 lbs (2.1 kg). For the pilot using an extra-large SPH-4 helmet, 25-mm eyepiece ANVIS, ANVIS HUD, standard battery pack, lip light, and 20 oz of counterweight, the head supported weight would be approximately 7.3 lbs (3.3 kg). Of the 37 NVG IPs surveyed, the calculated mean head supported weight was 5.7 lbs (2.6 kg), standard deviation 0.47 lbs, with a range from 4.7 (2.1 kg) to 6.81 lbs (3.1 kg). If a protective mask such as the M-43 or XM-45 is included in the weight estimations, an additional 2 lbs would be added to the head supported weight.

In the epidemiological study, we found that the risk of head injury was significantly greater among AN/PVS-5 wearers compared to nonwearers in mishaps where the G-forces experienced by the crew were within human tolerances and the airframe maintained occupiable space for at least one of the crewmembers (ASMIS categories "survivable" and "partially survivable"). While many of the head injuries observed were minor (i.e., facial bruises and abrasions), the lack of significant differences in injury risk for ANVIS does not refute the existence of a positive association between head supported mass and head/neck injury risk. When designed, the ANVIS included a break-away feature for the goggle and dual battery pack, which was not found with the AN/PVS-5. Whether the higher head injury risks associated with the AN/PVS-5 were related to the goggle striking some object and then being driven into the wearer by one or more impacts, or whether the surgical tubing mounting system contributed to head injuries from a rebounding action, could not be determined from the injury data.

Conclusion

This report found that, in a small sample of pilots (N=56), 76 percent of the NVG instructor pilots (28/37) and all of the student pilots (N=19) were using counterweights with ANVIS at Fort Rucker, Alabama, and the upper range of the total head supported weight was approximately 6.8 pounds (3.1 kg). For the NVG instructor pilots, the median counterweight was 11.6 oz and the average was 13 oz. Although the ANVIS, battery pack, and counterweights will break-away under certain acceleration limits, increasing head supported weight and the resultant forces on the neck during a mishap would be expected to increase the probability of a severe neck injury. However, the increase in the percent of neck injuries from the use of night vision goggles was not found to be statistically significant from an epidemiological study of Army helicopter mishaps. On the other hand, the percent increase in head injuries associated with night vision goggles was statistically significant (.05 level), but was attributed to the older obsolete AN/PVS-5 NVG and not the ANVIS. When the 25-mm eyepiece ANVIS and ANVIS HUDs become more prevalent in routine training, the counterweight survey will be repeated to determine any differences in the percent use and amount of the counterweights.

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Appendix A.
Questionnaire and briefing to the pilots

NVG Counterweight Survey

Date_____ Unit _____Present aircraft type_____

ANVIS eyepiece type (18-mm) (25-mm) ANVIS hours _____ All NVG hours _____

Helmet type (SPH-4) (SPH-4B, dual visor) (Other)_____

Type helmet suspension (Sling) (TPL) (Other)_____

Helmet size (Regular) (X-Large) (Other)_____

1. Do you presently use a counterweight with ANVIS? (Yes) (No)

2. If you use a counterweight with ANVIS, Rank at least the first three Reasons, where 1 is the most important, 2 is the next, and so on. Use "other", if a reason is not listed. If you do not use a counterweight, then just check the NA (not applicable) line.

_____ NA (not applicable), I do not use a counterweight with ANVIS

_____ because my NVG instructor recommended it

_____ to keep eyes aligned with ANVIS eyepieces

_____ to reduce helmet from rotating forward

_____ to relieve neck strain

_____ other (please state _____)

3. If you use a TPL, was the TPL heat treated? (NA) (YES) (No)

4. If you had the TPL modified, how many dimple liners were removed?_____ (NA)

5. Do you obtain a full field of view with ANVIS? (Yes) (No) (Don't Know)

6. Which statement best describes your fore-aft adjustment position?

(A) I place the eyepieces as close to the eyes as possible.

(B) I place the eyepieces as far from the eyes as possible.

(C) I place the eyepieces just close enough to my eyes to obtain a full field of view through the goggles with sufficient look around to read my instruments.

(D) Other. (please describe _____
_____

7. If you attach any other equipment to the helmet or ANVIS such as a lip light or ANVIS HUD, please list. (NA)

_____

(Backside of questionnaire)

Comments:

To be filled out by USAARL personnel or designee

Counterweight amount _____ Type counterweight_____

ANVIS Counterweight Survey

The purpose of this study is to determine "why" you use a counterweight, the materials you use for a counterweight, and how much the counterweight weighs. Other questions deal with your NVG experience, how you position the fore-aft adjustment, helmet type, size and modifications. The information will be used as a base line for possible later comparison with the counterweights used with future NVG systems that may have different weights and centers of gravity.

Participation in this survey is STRICTLY VOLUNTARY. If you volunteer to participate in this study, you must complete this form to include your name, SSN, and age on the first page of this form, and your signature, date, and permanent address at the bottom of this page. Verification of your signature must also be witnessed and dated as indicated.

Answers are "fill in the blank", circle the best choice listed in parentheses ( ), or rank order. Any comments or clarification to your answers of any questions can be added in the comments section. We would like to weigh and inspect your counterweight, but this is also optional.

There are no identified physical or psychological risks associated with this study.

There are no benefits from your participation in this study.

USAARL POCs for this survey are Bill McLean, tel. # 5-6813, and Joe McEntire, tel. # 5-6896.

Are there any questions?

Appendix B.

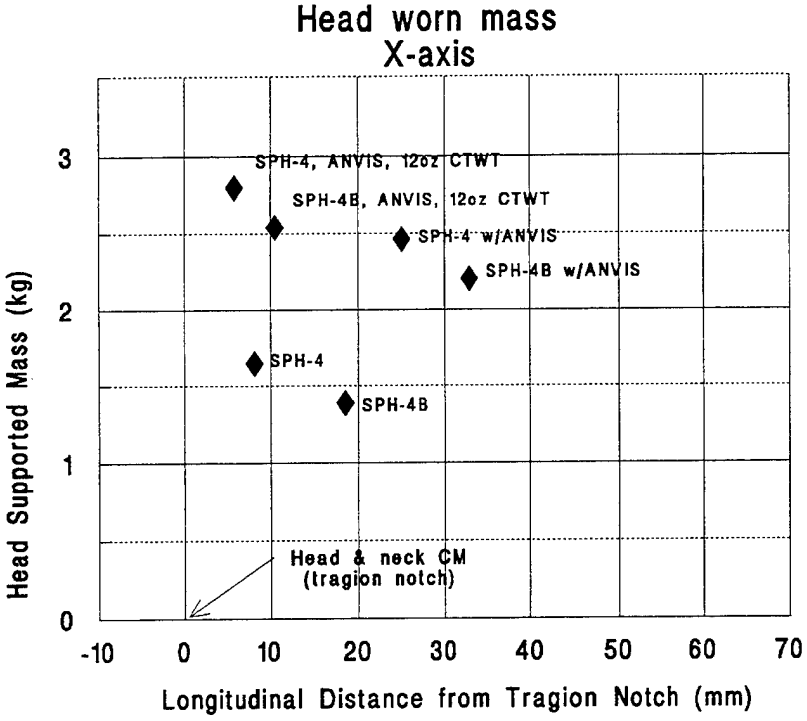
Head supported components and weights

SPH-4 and SPH-4B helmet weight and C.G.
with ANVIS and counterweight

Component weights

Item	Weight	Description
SPH-4 helmet		
regular	56.3 oz. (3.5 lb)	fiberglass shell and reinforced
X-Large	59.2 oz. (3.7 lb)	ANVIS single visor cover
SPH-4B helmet		
regular	47.4 oz. (3.0 lb)	composite shell and dual visor
X-Large	51.2 oz. (3.2 lb)	
ANVIS		
18-mm eyepieces	18.5 oz.	
25-mm eyepieces	19.0 oz.	
ANVIS battery pack		
with 4 AA batteries	9.2 to 10.2 oz.	2 AA 1.5 volt batteries are joined in series
with 2 lithium batteries	6.7 oz.	first batteries were 3 volt lithium for cold temperatures
ANVIS HUD	6.0 oz.	attaches to ANVIS objective lens and presents symbology
ANVIS ODA	2.4 oz.	OH-58D version of HUD
2 rolls pennies	9.5 oz.	
2 D cell batteries	9.2 oz.	sometimes used as a counterweight
lip lights (1 to 3 LEDs)		
on helmet microphone	0.1 to 0.4 oz.	different manufacturers and designs
2 AA batteries and case		
for lip lights	1.9 to 2.2 oz.	
counterweight sack	0.4 oz.	

SPH-4 and SPH-4B helmet weight and C.G. plots with ANVIS and counterweights



NOTE:
Helmet size is X-large with ANVIS mount.
ANVIS includes 10.2 oz dual battery pack.